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<p>(21) International Application Number: PCT/US92/03859 (22) International Filing Date: 7 May 1992 (07.05.92) (30) Priority data: 696,637 7 May 1991 (07.05.91) US (71) Applicant: DYNAGEN, INC. [US/US]; 99 Erie Street, Cambridge, MA 02139 (US). (72) Inventors: KITCHELL, Judith, P. ; 44 Pierrepont Road, Newton, MA 02162 (US). MUNI, Indu, A. ; 5 Westward Circle, N. Reading, MA 01864 (US). BOYER, Yvonne, N. ; 2 Hawthorne Boulevard, Salem, MA 01970 (US). (74) Agent: JANIUK, Anthony, J.; Wolf, Greenfield &amp; Sacks, 600 Atlantic Avenue, Boston, MA 02210 (US).</p>		<p>(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), MC (European patent), NL (European patent), NO, SE (European patent).  <b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
<p>(54) Title: A CONTROLLED, SUSTAINED RELEASE DELIVERY SYSTEM FOR TREATING DRUG DEPENDENCY</p> <p>(57) Abstract</p> <p>A drug delivery system useful in treating an individual for a drug dependence is described. One embodiment of the system is useful for aiding individuals in the cessation of smoking or chewing nicotine containing products is described. The delivery system includes a physical constraint modulation system (PCMS<sup>TM</sup>) containing lobeline. The drug delivery system is capable of delivering lobeline to an individual in a controlled, sustained release manner and providing long-term therapeutic levels of lobeline to the individual. The delivery of lobeline in such a manner reduces or eliminates the individual's smoking or chewing habit. The PCMS may be a biodegradable polymer containing the lobeline capable of subcutaneous or intramuscular injection or implantation into the individual or may be part of a transdermal patch containing lobeline. Also described are methods of using the drug delivery systems in treating other drug dependencies and kits containing the drug delivery systems.</p>		

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A CONTROLLED, SUSTAINED RELEASE DELIVERY  
SYSTEM FOR TREATING DRUG DEPENDENCY

Related Application

This application is a continuation-in-part of related application serial No. 07/696,637, filed May 7, 1991 for A CONTROLLED, SUSTAINED RELEASE DELIVERY SYSTEM FOR SMOKING CESSATION.

Field of the Invention

Embodiments of the present invention feature drug delivery systems which deliver a controlled, sustained release of a drug substitute for the treatment of drug dependency.

Background

Drug addiction is typically characterized by a physical, as well as psychological dependence. To treat drug dependence, a drug substitute is administered to the addict according to an established treatment schedule. Adherence to the treatment schedule determines the effectiveness of the treatment. Accordingly, such dependencies are treated as part of a drug cessation program which includes both administration of a drug substitute and behavior modification counseling.

Examples of drug dependencies displaying both physical and psychological addiction include

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dependences on heroin, non-opiate sedatives (including barbiturates), benzodiazepines, cocaine and alcohol. Nicotine dependence is one example of a drugug dependency in which the drug of abuse exerts both a physical and psychological addiction.

Recent studies have linked smoking to both heart disease and cancer. Smoking also may adversely affect a fetus during pregnancy. A trend thus has developed towards people wanting to quit smoking. It is difficult for a person to quit smoking since nicotine, a component of tobacco, is an addictive drug ("Nicotine Addiction", a report of the Surgeon General, 1988). Presently available over-the-counter products for aiding in smoking cessation are not always successful.

Lobeline is an alkaloid obtained from the dried leaves and tops of the Indian tobacco herb, Lobelia inflata. Lobeline is a substituted piperidine compound that produces several physiological affects, some of which are similar to those produced by nicotine. Lobeline's potency in causing these physiological effects is significantly less than that of nicotine. Because of lobeline's pharmacological similarities with nicotine, it has been considered as a substitute for nicotine which assists individuals in lessening addiction to nicotine and in ceasing to smoke cigarettes. Although use of lobeline as a smoking cessation aid has been studied since at least the 1930's, its efficacy has been a matter of dispute. Moreover, severe, undesirable side-effects

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have been reported.

Presently available over-the-counter products (Nikoban®, Bantron®, CigArrest™, and Nic-Fit) offer lobeline hemi-sulfate as an aid to smoking cessation. These products are taken orally and the recommended daily doses are up to 6 milligrams. Antacids are incorporated in some of the products to overcome gastrointestinal discomfort, a side effect similar to that caused by nicotine. Higher oral doses may not be feasible because of the concomitant gastric upset. The efficacy of oral doses of lobeline at 6 mg/per day in aiding smoking cessation has not been proven.

The presently available over-the-counter lobeline formulations for treating smoking addiction either do not appear to provide or do not appear to maintain therapeutic blood or tissue levels of lobeline. This may be because of the low dose of lobeline in the lobeline formulations, poor absorption of oral formulations or metabolism which does not allow lobeline to reach critical therapeutic levels.

Although there have been reports of using lobeline in oral formulations at doses in excess of 10 mg/day, nausea and even vomiting have been associated with such doses. A further problem with such oral dose regimens is that self-administration of as many as 18 tablets per day has been required. This not only may be considered by patients as intrusive, but also does not permit the physician to

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carefully control dosage.

Kalyuzhnyy (J. of Neural Psychiat 68: 1864-1870 (1968)) describes the use of intramuscular doses of lobeline hemi-sulfate up to 10 mg/per injection, administered twice daily. Although the amount of lobeline administered by Kalyuzhnyy was reported to be effective, the procedure for administration does not lend itself to practical application because it requires twice daily injections of lobeline.

Takagi et al. (JP 1-197,435) describe a smoking-substitute adhesive agent containing 0.5 to 10 percent lobeline by weight. Takagi et al. report that blood concentrations of lobeline remained higher for several hours compared to blood concentrations of nicotine delivered using the same adhesive agent delivery system. Takagi et al. did not report the amounts of lobeline released from the adhesive agent.

The accepted program for treating heroin addiction has been to incorporate a drug substitute, e.g., methadone, into an oral formulation for administration to the drug addict. The effectiveness of such treatment depends largely upon adherence to an established treatment schedule. Accordingly, out-patients are provided with a limited number of doses with specific instructions as to frequency of use. Oral doses are often provided as a powder or tablet which can be readily dissolved in fruit juices for administration. One problem associated with such water soluble compositions is that the composition can alternatively be dissolved in water, filtered and

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concentrated to provide a solution sufficiently rich in the drug substitute to be abused by the addict, i.e., injected in lieu of the drug of abuse.

#### Summary of the Invention

The present invention provides a drug delivery system useful in treating an individual for drug dependence. Examples of drug dependencies include dependencies on nicotine, heroin, non-opiate sedatives, benzodiazepine, cocaine and alcohol.

The system is used to release a therapeutic amount of a drug substitute for the treatment of drug dependence. As used herein, drug substitute refers to a drug used to treat a drug dependence. Typically, such drug substitutes function by binding to receptors specific for the drug of abuse. Examples of drug substitutes for various types of dependencies are provided in Table I.

TABLE I.  
Drug Dependencies and Corresponding Drug Substitutes

<u>Drug Dependence</u>	<u>Drug Substitute</u>
Nicotine	lobeline
Heroin	dl-methadone l-methadone naltrexone buprenorphine levo-alpha acetylmethadol
Non-opiate sedatives (e.g., barbiturates)	phenobarbitol chlordiazepoxide diazepam



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Benzodiazepines	long-acting benzodiazepines such as: chlorzepate diazepam flurazepam
Cocaine	bromocriptine desipramine buprenorphine amfebutamone carbamazepine fluoxetine flupenthixol maprotilene gepirone mazindol
Alcohol	naltrexone buspirone fluoxetine ondansetron disulfiram nadide nitretazole calcium cyanamide citrated

In regard to nicotine dependence, the system can be used in aiding individuals in the cessation of smoking or chewing nicotine containing products by providing a drug delivery system for releasing a controlled amount of lobeline. The delivery system eliminates the need for twice daily injections or multiple daily doses of lobeline, and is capable of providing lobeline at therapeutically effective levels for long periods of time.

The drug delivery system has a physical constraint modulation system (hereinafter PCMS) containing the drug substitute, such as lobeline. It

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is constructed and arranged so that the drug substitute, such as lobeline, is delivered to the individual at therapeutic levels in a controlled, sustained release manner. For example, the delivery of lobeline in such a manner is useful for treating nicotine dependence, i.e., lobeline delivery reduces or eliminates the individual's desire to smoke or chew nicotine containing products. Likewise, the delivery of a drug substitute is useful for treating other types of drug addictions, such as dependencies on heroin, non-opiate sedatives (including barbiturates), benzodiazepine, cocaine and alcohol.

The PCMS may involve a biodegradable polymer suitable for subcutaneous or intramuscular injection into the individual or may be part of a transdermal patch applied to the skin of an individual. In the PCMS utilizing the biodegradable polymer, the form of the delivery system preferably is microparticles which are suspended in a pharmaceutically acceptable vehicle just prior to subcutaneous or intramuscular injection.

The PCMS utilizing the transdermal patch may employ, for example, a diffusion layer matrix containing the drug substitute, such as lobeline, or may be a multicompartamental patch containing the drug substitute in a first compartment and a delivery substance in a second compartment. The drug substitute, e.g., lobeline, is released from the first compartment when contacted with the delivery substance. The transdermal patch having the

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diffusion layer typically is replaced every seven days and, the multicompartamental transdermal patch typically is replaced on a daily basis.

The present invention also pertains to a method for treating an individual for drug dependence and includes, for example, treating an individual for nicotine dependence, i.e., cessation of smoking or chewing nicotine containing products. The method includes administering the drug substitute, e.g., lobeline, to the individual in a controlled, sustained release manner such that long-term therapeutic levels of the drug substitute, e.g., lobeline, are provided to the individual. This method preferably is carried out using the drug delivery systems described above. The drug substitute, e.g., lobeline, may be administered to the individual at time periods easily integrated with behavioral modification support programs.

The present invention also pertains to kits useful in treating drug dependence, such as nicotine dependence. For example, the kits are useful in aiding individuals in the cessation of smoking or chewing nicotine containing products. The kits contain a sustained release system of the type herein described capable of delivering long-term therapeutic levels of a drug substitute, e.g., lobeline, along with instructions providing information to the user and/or health care provider regarding the use of the system for treating the drug dependence, e.g., a lobeline kit for treating nicotine dependence

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includes instructions useful for aiding in the cessation of smoking or chewing a nicotine containing product. The preferred kits for treating nicotine dependence include a delivery system capable of providing sustained release of therapeutic levels of lobeline for at least three weeks.

It is an object of the invention to provide a method for treating an individual for a drug dependence by administering a therapeutic level of a drug substitute to the individual in a controlled, sustained release manner.

Yet another object of the invention is to provide a method, drug delivery system and/or kit for treating various types of drug dependencies, e.g., nicotine, heroin, non-opiate sedative (including barbiturate), benzodiazepine, cocaine and alcohol dependencies.

It is an object of the invention to provide a controlled, sustained release delivery system for passively providing long-term therapeutic levels of a drug substitute, e.g., lobeline to individuals.

It is another object of the invention to provide a delivery system capable of delivering lobeline to an individual in a manner which reduces or eliminates the individual's tobacco smoking or chewing habit.

It is yet another object of the invention to provide a drug delivery system for delivering a drug substitute, e.g., lobeline to an individual without passage of the drug through the gastrointestinal (GI) tract thereby minimizing GI side effects.

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It is yet a further object of the invention to provide a drug delivery system for delivering a drug substitute, e.g., lobeline, in doses which are not overly intrusive to the individual and are easily integrated with a behavioral modification program designed to help the individual overcome the drug dependence, e.g., quit smoking.

It is yet another object of the invention to provide self-administratable, drug delivery systems for delivering a drug substitute, e.g., lobeline, in therapeutically effective amounts.

Still another object of the invention is to provide therapeutic levels of a drug substitute, e.g., lobeline, without the need for multiple, daily doses.

#### Brief Description of the Drawings

Figures 1A, 1B and 1C depict a lobeline containing microparticle, microcapsule and elongated rod, respectively.

Figure 2 depicts a transdermal patch having a diffusion layer matrix.

Figure 3 depicts a multicompartmental transdermal patch.

Figure 4 depicts a kit containing four packaged transdermal patches having a diffusion layer matrix along with instructions.

Figure 5 depicts a kit containing twenty-eight packaged multicompartmental transdermal patches along with instructions.

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Figure 6 depicts a kit including a syringe containing microparticles of a biodegradable polymer containing lobeline, a container of a pharmaceutically acceptable vehicle, and instructions.

Figure 7 depicts the in vitro release of lobeline free base from PLGA microparticles (150-180 $\mu$ ) at 30%, 40%, and 50% lobeline loading.

Figure 8 depicts the in vitro release of lobeline free base from PLGA microparticles (38-106 $\mu$ ) at 30% lobeline loading.

Figure 9 depicts the in vivo release of lobeline free base, expressed as the percentage of lobeline remaining at the injection site, from a formulation containing 30% lobeline free base and a formulation containing 40% lobeline free base.

Figure 10 depicts the in vivo effect of lobeline dose on the number of cigarettes smoked.

Figure 11 depicts the in vivo effect of lobeline dose on the number of smoking puffs.

Figure 12 depicts the in vivo release of lobeline free base, from PLGA microparticles at 35 % lobeline loading.

Figure 13 depicts the in vivo effect of a lobeline-containing microparticle formulation on the number of cigarettes smoked by human volunteers following subcutaneous injection of the microparticles.

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Detailed Description

The present invention pertains to a method for treating an individual for drug dependence. The method comprises administering a therapeutic level of a drug substitute to the individual in a controlled, sustained release manner over a period of time having a duration of at least one day. The method is useful for treating a broad spectrum of drug dependencies, including dependencies on nicotine, heroin, non-opiate sedatives (including barbiturate) benzodiazepine, cocaine and alcohol. The method is particularly useful in combination with a drug cessation program. Such programs combine therapies for treating an individual's physical drug dependence with behavior modification counseling directed to reducing the individual's psychological dependence on the drug.

The method is useful, for example, for treating nicotine dependence, wherein the preferred methods of the invention involve administration regimens that are easily integrated with smoking cessation behavioral modification programs. However, methods for treating other drug dependencies can likewise involve administration regimens that are easily integrated with drug cessation programs including behavior modification counseling. These programs are designed to teach individuals how to quit or reduce their drug dependence, e.g., use of nicotine containing products, by modifying their behavior. Typically, these programs involve regularly

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scheduled, e.g. weekly or biweekly, meetings with counselors.

The language "time periods easily integrated with smoking cessation behavioral modification support programs" is intended to include time periods which coincide with regularly scheduled meetings with counselors, e.g. weekly or biweekly. For example, the delivery system may be designed such that weekly subcutaneous or intramuscular injections are required to maintain a therapeutic level of lobeline in the individual's circulatory system. The weekly injections are easily coordinated with a weekly appointment with a counselor from a behavioral modification support program. Preferably, the injection is administered by medical personnel or the counselor. The individual may schedule a weekly appointment for obtaining both the injection and any necessary behavioral support counseling.

The present invention also pertains to a drug delivery system useful for treating a drug dependence. Thus, for example, the drug delivery system is useful for treating nicotine dependence, i.e., aiding an individual in the cessation of smoking or chewing nicotine containing products. The delivery system includes a physical constraint modulation system (PCMS) containing a drug substitute, e.g., lobeline. The system is constructed and arranged to deliver a therapeutic level of the drug substitute to the individual in a controlled, sustained release manner for a period of



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time having a duration of at least one day. Typically, the delivery system is constructed and arranged such that the physical constraint modulation system subcutaneously, intramuscularly or transdermally delivers the drug substitute into the circulatory system.

The drug delivery system is used to provide long-term therapeutic levels of a drug substitute, such as lobeline, to the individual. Delivering the drug substitute in such a manner reduces or eliminates the individual's physical dependence on the drug of abuse. In connection with treating nicotine dependence, delivering lobeline in such a manner reduces or eliminates the individual's smoking or chewing habit.

The term individual is intended to include individuals who suffer from a drug dependency. Typically, such individuals are physically, as well as psychologically, addicted to a drug of abuse. Treatment for such individuals is directed both to treating the physical addiction, e.g., by administration of a drug substitute, and behavior modification counseling.

The term drug dependence refers to a dependence on a drug, which dependence is treatable by administration to the individual of a drug substitute. An exemplary list of drug dependencies with the corresponding drug substitutes is provided in Table I. The term drug substitute is also intended to encompass structural equivalents of the

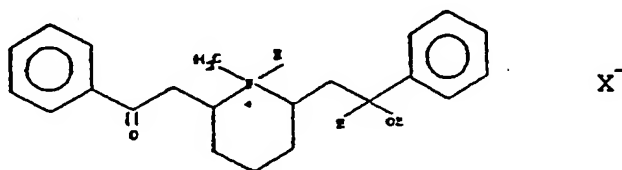
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drug substitute having the same or similar functional characteristics.

With respect to nicotine dependence, individuals refers to individuals who smoke or chew nicotine containing products. The nicotine containing products may be any product containing nicotine, e.g. cigarettes, pipe tobacco, and chewing tobacco.

The term PCMS is intended to include substances or components, e.g. solids, liquids, gels or layers, capable of releasing a drug substitute, such as lobeline, in a sustained release manner. Examples of PCMS which are useful within the present invention include biodegradable polymers and parts of transdermal patches.

The term lobeline is intended to include 2-[6-(B-hydroxyphenethyl)-1-methyl-2-piperidyl] acetophenone as shown below. The lobeline may be in its free base form or may be in the form of a water soluble salt, e.g. hydrochloride or sulfate salts, or a less soluble salt, e.g. palmoate.



where X is the anion.

The term lobeline also is intended to encompass

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structural equivalents of the above compound which share the same or similar functional characteristics. Structural equivalents are structurally similar to the above compound but may have one or more substituents on the core structure. For example, substituents may be placed on either of the benzene rings as long as the substituents do not adversely affect the compound's ability to act as a substitute for nicotine. Examples of substituents may include lower alkyl groups, e.g. methyl, ethyl and propyl groups. For a further example, the methyl group of the piperidyl nitrogen may be substituted with a different lower alkyl group, e.g. ethyl or propyl group.

The term "controlled, sustained release manner" is intended to include the delivery of the drug substitute, e.g., lobeline, in a manner in which only a portion of the drug substitute is released from the PCMS at a given moment while the remaining drug substitute is retained in the PCMS and released gradually over an extended period of time. The extended period of time is a period of time having a duration of at least a day (twenty-four hours), but may be longer such as up to about thirty days or even ninety days.

The long-term therapeutic levels of lobeline are intended to include those levels of lobeline sufficient to significantly reduce or eliminate the individual's habit for smoking or chewing a nicotine containing product over an extended period of time,

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as defined above. Examples of such therapeutic levels include from about five to about thirty milligrams of lobeline per day, preferably averaging between about ten to about twenty milligrams per day over time periods of about one to at least about thirty days. These doses are based on the free base form of lobeline. This dose of about five to about thirty mg of lobeline is the amount of lobeline released from the PCMS and does not refer to the level of lobeline detected in the individual's circulatory system.

The PCMS of the drug delivery system may be in a form suitable for subcutaneous or intramuscular injection, such as combined with a biodegradable polymer. The term biodegradable polymer includes polymers capable of degrading in vivo and delivering the drug substitute, e.g., lobeline, in a controlled, sustained release manner such that long-term therapeutic levels of the drug substitute are attainable. The polymer is selected such that it does not cause significant adverse effects to the individual when administered in vivo. Examples of biodegradable polymers which may be used in this invention include poly(lactic/glycolic)acid copolymers (PLGA), polylactic acid (PLA), polyglycolic acid (PGA), polyesters, e.g., polyorthoesters, polylactones, polyanhydrides, and polyaminoacids. The preferred biodegradable polymer is PLGA.

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Polymers prepared from glycolide and lactide dimers e.g., PLGA, PLA and PGA, are known to undergo slow hydrolysis when implanted in tissue and the by-products of their hydrolysis (lactic and glycolic acids) both are normal metabolites. PLGA, PLA, and PGA are believed to be non-toxic, are relatively non-inflammatory, and non-tissue reactive. The polymers also exhibit moderate strength and tension, compression and pliability. Hereinafter, the term PLGAs will be used to encompass PLA, PGA, and PLGA.

The specific lactide/glycolide ratio of the PLGAs polymer and the molecular weight of the polymer are factors considered when designing the drug delivery system. There are differences in the hydrophobicity and crystallinity of lactic acid, and glycolic acid, and the use of a fast-hydrolyzing polymer (low molecular weight, low lactide content) for rapid ultimate clearance of a drug substitute such as lobeline, is balanced with the need for the sustained release of relatively soluble lobeline provided by a slow-hydrolyzing polymer (high molecular weight, high lactide content). Based on these needs, the preferred polymers for delivery of lobeline are in the range of about 50:50 lactide/glycolide to about 85:15 lactide/glycolide. The preferred polymers also have molecular weights in the range of about 50,000 to about 150,000 daltons, preferably about 100,000 daltons.

Similarly, with respect to other drug substitutes, the preferred polymers are selected on

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the basis of the specific lactide/glycolide ratio of the PLGAs polymer, the molecular weight of the polymer, differences in the hydrophobicity and crystallinity of lactic acid, and glycolic acid, and the relative solubility of the drug substitute.

To prepare a drug delivery system useful for treating nicotine dependence, lobeline is loaded into the polymer in an amount which allows sustained release of the lobeline from the polymer at the desired therapeutic levels. The preferred loading of lobeline into a PLGA polymer having a lactide/glycolide content of about 85:15 and a molecular weight of about 100,000 daltons, is about 20 to about 65%, more preferably about 30 to about 50%, most preferably about 30 to about 40% by weight of lobeline based on the weight of the polymer.

The formulation of the biodegradable polymer and the drug substitute, e.g., lobeline, should be such that it permits subcutaneous or intramuscular deposition. These include injectable formulations such as microparticles, microcapsules or elongated rods of the polymer/lobeline composition.

The figures and examples discussed herein describe drug delivery systems in which the drug substitute is lobeline. These descriptions are exemplary only and are not intended to limit the invention in any way. The lobeline controlled release delivery system is a model system for drug delivery systems for other drug substitutes as well.

Figures 1A-1C depict a lobeline containing

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microparticle, microcapsule and elongated rod respectively. The lobeline may be distributed throughout the biodegradable polymer 2 as shown in Figures 1A and 1C. Alternatively, the lobeline 1 may be encapsulated within the biodegradable polymer 2 as shown in Figure 1B.

The microparticles, microcapsules, and elongated rods of the biodegradable polymer are of a size capable of being subcutaneously or intramuscular injected or implanted while releasing the drug substitute, e.g., lobeline, in a controlled, sustained release manner. Examples of sizes for microparticles include in the range from about 38 to about 250 microns, most preferably 38 to about 106 microns. Examples of sizes for microcapsules include in the range from about 10 to about 250 microns. Examples of sizes for elongated rods include a diameter in the range of about 1 to 4 mm and a length in the range of about 0.5 to about 3 cm.

The preferred form of the biodegradable polymer is microparticles. The microparticles preferably are suspended in a pharmaceutically acceptable vehicle just prior to the time of injection. The pharmaceutically acceptable vehicle is selected such that it can form a suspension with and permit delivery of the microparticles and such that it does not have a significant adverse effect on lobeline's ability to substitute for nicotine when administered in vivo.

The pharmaceutically acceptable vehicle or

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diluent, for other drug substitutes is selected in a similar manner. A pharmaceutically acceptable vehicle is selected which will permit delivery of the microparticles but which will not adversely effect the ability of the drug substitute to substitute for the drug of abuse when administered in vivo.

Examples of pharmaceutically acceptable vehicles useful for lobeline delivery, include, for example, solutions prepared as follows: Formulation No. 1 - 0.38 g carboxymethylcellulose, 3.75 g mannitol, and 0.08 g Tween 80 in 20 ml. of distilled water; Formulation No. 2 (preferred) - 0.0127 g carboxymethylcellulose, 0.056 g mannitol, 0.027 g Tween 80 in 20 ml. of distilled water. A syringe containing the microparticles can be used to draw up the pharmaceutically acceptable vehicle creating the suspension. Other methods of preparing the suspension of course may be used. The suspension may be created outside of the syringe and then drawn into the syringe. The suspension is injected into the individual preferably at time periods easily integrated with behavioral modification support programs, such as smoking cessation programs.

With respect to lobeline-containing microparticles, it should be understood that the microparticles cannot be suspended in the vehicle for a prolonged period of time because significant amounts of the lobeline would be released from the microparticles into the vehicle. Preferably the suspension is injected within about an hour after



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being prepared. Thus, the rate at which a drug substitute is released from microparticles in vitro is determined for each drug substitute. The in vitro release rate is used to establish the recommended time period within which the suspension should be injected for each drug substitute-containing microparticle suspension.

When using microparticles (or other forms wherein the amount of drug released will gradually diminish over time), specific dosing procedures may be desirable. For example, if at least 15 mg of a drug substitute per day were the desired level of sustained release, a dose of microparticles might be prepared to deliver 20 mg per day on day one, with release diminishing to 14 mg per day on day eight. As will be readily understood, the second dose would need to be smaller than the first dose to attain a level of 15 mg per day for the next seven days due to the continued release of the drug substitute from the residual microparticles of the first dose. Thus, certain PCMS delivery systems will require different dosing schemes.

However, such tapering off of subsequent dose concentrations is unnecessary for drug substitutes which are non-addictive and/or rapidly cleared from the body. At present, lobeline is believed to be non-addictive and rapidly cleared from the circulatory system. It is believed that such rapid clearance is due to the binding of lobeline to nicotine receptors located in the brain. Thus,

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although lobeline may be rapidly cleared from the circulatory system, it may persist in the brain for a substantially longer period of time.

The PCMS also may be part of a transdermal patch. Transdermal patches have a variety of advantages including avoidance of the gastro-intestinal tract, sustained action which readily can be adjusted, self-administration and the ability to immediately discontinue dosage. The term transdermal patch is intended to include patches capable of being affixed to the skin of an individual and having a part or component capable of delivering a drug substitute, e.g., lobeline, in a controlled sustained release manner. Examples of types of patches useful in this invention include those having a diffusion layer matrix and/or multicompartamental type patches. These will be described in detail below.

There are many transdermal patches known to those of ordinary skill in the art and well described in the prior art. One such patch useful according to the invention is shown generally in Fig. 2. The patch of Fig. 2 involves a diffusion matrix layer that uses a reticulated macroporous polymeric foam as a framework for holding a viscoelastic lobeline-polymer mixture. The patch 10 is a 4-layer, laminated composite that is adapted to be adhered to the skin. The outermost layer, backing layer 12, functions as the primary structural element of the device as well as serving as a protective covering to

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prevent the lobeline from being transmitted from the device via the outermost surface. Backing layer 12 preferably is made of a sheet or film of a resilient elastomer of about 10-75 microns thick. Examples of such elastomers include polyether block amide copolymers, polyethylene methacrylate block copolymers, polyurethanes, silicon elastomers and the like.

The lobeline-containing matrix layer 14 functions as a reservoir for lobeline, an enhancer, and optionally a pressure sensitive adhesive. The framework of the matrix is a reticulated macroporous polymeric foam 16. Preferably the network is essentially completely open pores (90% or greater). The pore rating of the reticulated foam will normally be in the range of about 10-40 pores per linear centimeter and the density (unfilled) will typically be in the range of about 0.01 to 0.5g/cm<sup>3</sup>. Suitable polymers from which such foam frameworks may be manufactured include polyurethanes and polyethylenes.

A pressure sensitive adhesive layer 18 covers the exposed face of the matrix layer 14 and a release liner 20 covers the pressure sensitive adhesive. The pressure sensitive adhesive layer 14 is a medical grade adhesive composition having a thickness normally between about 25 and 100 microns. An example of such an adhesive is polydimethylsiloxane (Dow Corning 355 medical grade adhesive).

The pores of the foam are wholly or partly filled with a viscoelastic hydrophobic

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lobeline-permeable polymer and an enhancer. The polymer acts as a carrier for the lobeline and the enhancer acts to control the solubility of the lobeline in the polymer and/or absorption of the drug into the skin. The hydrophobic polymer renders the device water-resistant and prevents liquid water from being absorbed by the device, thereby increasing its functionality and wearability. Examples of such polymers are polysiloxanes (silicone polymers), hydrophobic polyacrylates, polyurethanes, plasticized ethylene-vinyl acetate copolymers and the like. An example of a useful enhancer includes Azone™. The mixture including the lobeline optionally includes an anti-pruritic agent.

Devices of the foregoing nature are generally described in U.S. patent 4,911,916, entitled "Diffusion Matrix for Transdermal Drug Administration and Transdermal Drug Delivery Devices Including Same", issued March 27, 1990, the entire disclosure of which is incorporated herein by reference. Such patches may be configured to contain sufficient lobeline to release from about five to about thirty milligrams of lobeline per day. Preferably such patches are configured to hold sufficient lobeline to release from about five to about thirty milligrams per day for seven days, such that a single patch may be worn for one week.

The optimum dose range, i.e., the range of doses with which the drug exhibits maximum therapeutic effect and minimum adverse side effects is determined

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empirically, for any drug substitute. The patch or other delivery system is configured and formulated to contain sufficient drug substitute to release a dose within the optimum dose range for the desired period of time.

Another patch useful according to the invention is shown generally in Fig. 3. The patch of Fig. 3 also is a 4-layer composite defining at least two separate compartments. One compartment contains the drug substitute, e.g., lobeline, and the other compartment contains a delivery substance that when mixed with lobeline permits the delivery of the lobeline transdermally. The patch 22 has a backing layer 24 sealed to a rate controlling membrane 26 in a manner to create two chambers, lobeline containing chamber 28 and a delivery substance containing chamber 30. An adhesive layer 32 covers the rate controlling membrane and a release sheet 34 covers the adhesive layer.

To form the device, a silanized polyester (or other suitable material treated with a releasing agent) approximately 75 microns thick, is used as a release sheet 34. The adhesive layer 32 is cast onto the release sheet, and may be for example polyisobutylene. The adhesive layer then is laminated to the rate controlling membrane 26, which may be about 100 microns thick. Ethylene-vinyl acetate may be employed for the control membrane.

Next, the materials which will become the contents of the lobeline containing chamber 28 and

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delivery substance chamber 30 are placed in separate areas on the rate controlling membrane 26. The material for the lobeline containing chamber 28 may be lobeline freebase and the material for the delivery substance containing chamber may be an alcoholic or aqueous/alcoholic solution.

Finally, a suitable backing 24 having a heat sealable coating on one surface is placed over the two areas which are to become chambers 28 and 30, and the device is heat sealed 36 around the perimeter and between the two areas to form the two chambers, 28 and 30. The heat seal 38 between the two chambers should be less secure than the heat seal 36 about the perimeter, so that the seal between the chambers will selectively burst under pressure applied by the user. In this manner, pressure may be applied to either one of the chambers to burst the seal between the chambers, thereby mixing the solution and the lobeline and dissolving the lobeline. The lobeline then is in a form which is capable of passing through the rate controlling membrane 26 for delivery to the skin of the user. As with the patch of Fig. 2, the chambers may include enhancers for affecting uptake of the lobeline across the skin.

Preferred forms of the foregoing patch are shown in greater detail in U.S. patent 4,917,676, issued April 17, 1990 and entitled "User-Activated Transdermal Therapeutic System", the entire disclosure of which is incorporated herein by reference. Such patches should contain sufficient

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lobeline to release from about five to about thirty milligrams of lobeline per day, and such patches are suitable to provide individual, daily patches.

This invention also pertains to kits useful in treating a drug dependence, such as those drug dependencies listed in Table I above. Kits for treating nicotine dependence are designed to aid an individual in the cessation of smoking. The kits for treating a drug dependence contain a PCMS delivery system according to the invention, as well as instructions for use. For example, the kit for treating nicotine dependence may contain at least one packaged transdermal patch 30 containing the lobeline along with instructions 32 providing information to the user and/or health care provider regarding the use of the patch. The number of transdermal patches provided in the kit may depend on the type of transdermal patch and the length of the smoking cessation program for which the kit is being designed, e.g. a three week or a four week smoking cessation program. In general, the course of treatment is between four and eight weeks, with a six to eight week program being fairly typical.

A transdermal patch containing the lobeline in a diffusion layer matrix typically is designed for long term drug delivery, e.g. about seven days. A kit for a four week smoking cessation program thus may contain four such packaged transdermal patches 30 as shown in Figure 4. The instructions 32 would inform the individual and/or health care provider to replace

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the patches on a weekly basis, e.g. Day 1 - patch no. 1, Day 8 - patch no. 2, etc.

A multicompartmental transdermal patch typically is designed for daily use. A kit for accompanying a three or four week smoking cessation program may contain twenty-one or twenty-eight, respectively, multicompartmental transdermal patches 30 as shown in Figure 5. The instructions 32 would inform an individual and/or health care provider to replace the transdermal patch on a daily basis and also would instruct the individual how to contact the lobeline in the first compartment with the delivery substance in the second compartment. For example, the individual may have to break a pressure sensitive seal between the two compartments.

The kit also may include at least one container 34 of an injectable or implantable PCMS delivery system and instructions 32 for use as shown in Figure 6. For example, the kit may include four to eight containers of polymer/lobeline microparticles useful for a four to six week smoking cessation program. As discussed above, each container may need to contain a different amount of microparticles/drug substitute to account for continued release of the drug substitute from microparticles remaining from each earlier dose. Alternatively, each container may contain the same quantity of microparticles/drug substitute with instructions to inject a reduced volume of resuspended microparticles/drug substitute on subsequent days of the treatment period. However,



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as noted above, it may not be necessary to decrease the dose level during the treatment program for drug substitutes which are non-addictive and/or rapidly cleared from the circulatory system.

The kit may further include at least one container 36 of a pharmaceutically acceptable vehicle. A syringe 38 also may be provided in the kit. The syringe may be pre-loaded with microparticles.

The following non-limiting examples further illustrate the present invention and provide a model for the design, development and optimization of drug delivery system capable of delivering a variety of drug substitutes.

Example 1 - Preparation of PLGA Microparticles  
Containing 30% Lobeline

Lobeline free base was obtained from Sigma Chemical company or prepared from lobeline sulfate obtained from Boehringer Ingelheim. The compound was characterized prior to use by UV spectroscopy, HPLC, and melting point. MEDISORB™ 8515DL lactide/glycolide bioresorbable polymer was obtained from DuPont. By specification the polymer is 85±5% lactide and 15±5% glycolide. The solvents (highest grade available) were obtained from Fisher Scientific. The polymer (3.5044 g) was dissolved in methylene chloride (23 ml.) as a 15% solution by weight. Lobeline (1.5006 g) was added to the polymer solution and the solution was stirred to insure complete mixing. The solution was then cast onto a

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clean, level piece of plate glass and spread with a Boston-Bradley adjustable blade. After evaporation of most of the solvent under a nitrogen stream, the film was peeled from the glass and vacuum desiccated.

The film formed in the casting step was of very low density because the solvent removal step left a very large void volume. The void volume was reduced to decrease permeation of fluids into the microparticles by a compression step, utilizing heat and hydraulic pressure. The film was extruded into rods with a Pasadena Hydraulic Press at about 70°C.

The extruded rods were ground into small particles using a commercial grinder with a cooled grinding chamber. Following grinding, the powder or small particles were passed through USP sieves to collect microparticles in the size ranges of about 38 to 106 $\mu$ , 106-150 $\mu$  and 150-180 $\mu$ . The microparticles containing 30% lobeline were collected.

Example 2 - Preparation of PLGA Microparticles containing 40% Lobeline

Example 1 was repeated except 1.0000 g of lobeline was placed in the jar with the polymer solution (1.501 g in 10 ml.). The microparticles containing 40% lobeline were formed and collected.

Example 3 - Preparation of PLGA Microparticles containing 50% Lobeline

Example 1 was repeated except 2.0016 g of lobeline was placed in the jar with the polymer solution (2.0016 g in 13 ml.). The microparticles containing 50% lobeline were formed and collected.

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Example 4 - The In vitro Release of Lobeline from PLGA

The PLGA/lobeline microparticles prepared in Examples 1, 2, and 3 were exposed to a phosphate buffered saline (PBS) solution under simulated sink conditions such that the drug would never reach more than 20% concentration in the buffer. The microparticles were placed in a thimble which was further placed in a test tube. Each day the thimble was moved to a new test tube and the lobeline content in the PBS solution was measured by extraction and concentration in an organic solvent, followed by UV analysis. Analysis of the buffer for lobeline content was made on a daily basis in the first two to three days, then on a weekly schedule thereafter. The results are depicted in Figure 7. Figure 7 depicts the release of lobeline free base from PLGA microparticles (150-180 $\mu$ ) at 30%, 40%, and 50% lobeline loading.

In none of the systems was the entire lobeline content released within one week. The 30% loading exhibited the slowest release. In the 30% loading, for the 150-180 $\mu$  particles, only 60% of the lobeline was released at the end of the first week.

Example 5 - The In vitro Release of Lobeline from PLGA

The method of analysis for this example differs from example 5 above in that the amount of lobeline left in the microparticles was measured after leaching the microparticles in the PBS solution. The

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total amount left in the microparticles was subtracted from the amount initially loaded into the microparticles to obtain the amount released.

The particles themselves differed as well, in that 38-106 $\mu$  sized microparticle, prepared as described in Example 1, were used. The microparticles were placed in an extraction thimble and covered with a glass wool plug. The thimbles were suspended in phosphate buffered saline containing 0.1% sodium azide. (9 thimbles/1.7 L). Each day the samples were removed, air dried, then vacuum dried. Each dry thimble was transferred to a large test tube and enough  $\text{CH}_2\text{Cl}_2$  was added to cover the thimble. The tube was vortexed to aid in dissolving the microparticle. To each tube, a measured volume of 0.01 N  $\text{H}_2\text{SO}_4$  was added. After mixing, the acid layer was removed and the step was repeated two to three times. The acid fractions were analyzed by UV for lobeline content. The total amount found was subtracted from the initial value to obtain the amount of lobeline released from the microparticles. The results are depicted in Figure 7. Figure 8 depicts the release of lobeline free base from PLGA microparticles (38-106 $\mu$ ) at 30% lobeline loading. The release was substantially constant over the first 10 days, tapering off over the last 4 days.

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Example 6 - Materials and Methods - Release Study  
of Two formulations in Rats

Formulations

Two formulations were tested. One formulation contained PLGA microparticles at 30% lobeline free base loading, and the other formulation contained PLGA microparticles at 40% lobeline free base loading. Within 1/2 hour of injection, a suspension containing 20 mg/ml of 30% formulation or 15 mg/ml of 40% formulation was prepared in diluent (.94 g carboxymethylcellulose, 9.38 g of D-Mannitol, .2 g polysorbate 80 (Tween 80) in 50 ml of water).

Animal Tests

Female Sprague-Dawley Rats (250-300 g) were used. Two animals were used as negative controls. An aliquot of 0.1 ml of vehicle was injected into the scapular region of each animal from a syringe fitted with a 22 gauge needle. On day 7, the two animals were sacrificed with CO<sub>2</sub> and the fatty tissue in the scapular region was removed.

The remaining animals were divided into two groups: those receiving the 30% formulation and those receiving the 40% formulation. From each group, four animals were used as positive controls. These animals were sacrificed and the fatty tissue and fascia in the scapular region was removed. Prior to the time of analysis, an aliquot of 0.1 ml of the formulation in vehicle was added to the tissue sample.

From each group, five additional subgroups were selected, representing different periods of time that

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the suspensions were left in the animal prior to obtaining a tissue sample: 4 hrs; 1 day; 2 days; 5 days; and 7 days. There were four animals in each of these subgroups.

The formulations were prepared for use as described above, and in every case a 0.1 ml aliquot was given. At the time of sacrifice, the fatty tissue and fascia in the scapular region of each animal was removed. In most, but not all cases, areas of tissue containing microparticles could be observed. It seems likely, however, that some of the microparticles migrated to areas beyond the excision site and that this material was thus not recovered.

#### Tissue Extraction

A tissue sample along with 2-3 ml  $\text{CH}_2\text{Cl}_2$  was placed in a short glass test tube. 100ul of a 1 mg/ml solution of triprolidine in  $\text{CH}_2\text{Cl}_2$  (internal standard) was added. Using the Tissue Tearor™ at 4500 - 8000 rpm, the sample was homogenized. The sample was transferred to a centrifuge tube with a teflon-lined screw cap and centrifuged for 7 min. The  $\text{CH}_2\text{Cl}_2$  was carefully pipetted out and transferred to a test tube. To this solution 1 ml of 0.01N  $\text{H}_2\text{SO}_4$  was added and the mixture was vortexed for 15-20 seconds. After separation of phases had occurred, the top (acid) layer was carefully removed with a pipette and the volume of this acid solution was measured. The acid solution was then transferred to a new, clean test

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tube or vial and filtered through 0.45u nylon filter prior to injection. The extraction of the  $\text{CH}_2\text{Cl}_2$  with acid was repeated until no more lobeline was detected or a maximum of five repeats.

#### Analysis

The acid samples were analyzed directly by HPLC. The amount of lobeline recovered was based on a standard curve of extracted lobeline concentration/internal standard concentration from spiked tissue control samples at various lobeline levels.

The HPLC System used was as follows: Waters 510 pump; Waters U6, injector; Waters Lambda Max 481 LC Spectrophotometer; spectra Physics SP 4270 Integrator; Phenomenex Partisil C<sub>8</sub> 5u 100X4.6 mm column with 30X4.6 mm guard column with same packing.

The mobile Phase was: 60% Phosphate Buffer, pH 3:40% (50:50  $\text{CH}_3\text{CN}/\text{MeOH}$ ). The flow rate was 1.2 ml/min; AUFS 1.0; detection at 249 nm; with 4 ul sample injection volume.

The results for 30% and 40% loaded microparticles were adjusted for an efficiency of extraction from excised tissue of 75.4%. No adjustment has been made for efficiency of recovery of microparticles from the animals.

The results (shown in Figure 9) are presented graphically, with the percent of the dose found in the tissue sample plotted against different kinds of treatment duration. The 30% loading exhibited a

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somewhat more linear release profile than the 40% loading.

Example 7 - Evaluation of Polyethylene "Pouches" for in vivo Release Studies in Rats

Formulation

The method of analysis for this example differs from example 6 above in that a single formulation containing PLGA microparticles at 35% lobeline free base loading was tested. The formulation was sealed into polyethylene bags with 20 $\mu$  pores prior to implantation in the scapular region of rats. These bags are porous enough for use in dissolution studies, yet have pores small enough to retain the microparticles (smallest particle diameter is 38 $\mu$ ).

Method

Polyethylene pouches (Biotek, Woburn, MA) were used. Twelve pouches were heat sealed without filling and cut to a size of about 1 cm x 1 cm. The remaining pouches were filled with approximately 4 mg of the above formulation each and similarly sealed and trimmed. Female Sprague Dawley rats of approximately 250 g each were obtained and quarantined. At time zero (T = 0), each rat was anesthetized and an incision just larger than the width of the pouch was made in the scapular area. The pouch was held with forceps and dipped into normal saline, then the forceps were used to slip the pouch under the skin. The incision was closed with



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one or two staples. On days 1, 2, 3 and 7, the pouches were removed from six controls (empty pouches) and six animals (for each time point) which had received the formulation. The method of removal was to anesthetize the animal and then to make an "I" shaped incision around the site of the pouch. The pouch was exposed by lifting the skin. Each pouch was rinsed in a normal saline solution and patted dry on a paper towel. The pouches were stored in sealed polyethylene bags overnight in the freezer and analyzed the next day. All animals were sacrificed immediately following removal of the pouches.

#### Sample Preparation for HPLC Analysis

Each pouch was cut open and its contents, along with the emptied, shredded pouch, were added to a 10 ml volumetric flask containing approximately 5 ml of acetonitrile. The flask was sonicated for 10 minutes, allowed to cool to room temperature (approximately 30 minutes) and the total volume in the flask was brought to 10 ml (i.e., "Q.S. to volume") with acetonitrile to prepare a "stock solution". Thereafter, 0.1 ml of the stock solution was accurately transferred to a 10 ml volumetric flask and Q.S. to volume with working diluent (described below). A 2.5 ml aliquot of this solution was then transferred to another 10 ml volumetric flask and Q.S. to volume with working diluent.

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HPLC Analysis

The acid samples were analyzed directly by HPLC. The amount of lobeline released from each pouch was based on a standard curve of lobeline concentration/internal standard concentration at various lobeline levels. HPLC analysis was performed as described above, with the following modifications.

Internal Standard Preparation: Triprolidine (10.0 mg) was accurately weighed and quantitatively transferred to a 10 ml type A volumetric flask and Q.S. to volume with mobile phase to give an Internal Standard Stock Solution having a Triprolidine concentration of 1.0 mg/ml. This stock solution was used to prepare the Working Diluent.

Working Diluent: A type A volumetric pipette was used to accurately transfer 1 ml of the Internal Standard Stock Solution to a 100 ml volumetric flask and Q.S. to volume with mobile phase (described below). Thereafter, 5 ml of the latter solution was accurately transferred (type A volumetric pipette) to a second 100 ml volumetric flask and Q.S. to volume with mobile phase to prepare the Working Diluent. The Working Diluent had a Triprolidine concentration of 500 ng/ml.

Standard Preparation: Lobeline reference standard (10.0 mg) was accurately weighed and quantitatively transferred to a 10 ml type A volumetric flask and Q.S. to volume with mobile phase to provide a Lobeline Stock Solution having a lobeline concentration of 1.0 mg/ml. A type A

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volumetric pipette was used to accurately transfer 1 ml of the Lobeline Stock Solution to a 10 ml volumetric flask and Q.S. to volume with Working Diluent. Thereafter, 1 ml of the latter solution was accurately transferred (type A volumetric pipette) to a second 10 ml volumetric flask and Q.S. to volume with Working Diluent to prepare the Standard Lobeline Solution. The Standard Lobeline Solution had a lobeline concentration of 0.01 mg/ml.

Mobile Phase: All solutions were degassed and filtered through a 0.2 micron membrane filter before use. The mobile phase was prepared by adding 200  $\mu$ l triethylamine to one liter of a mixture containing 62% 40 mM phosphoric acid (pH 3.00) and 38% acetonitrile.

Operating Conditions: The Column was Phenomenex/Partisil 5C8 (25.0 cm x 4.6 mm i.d.). The flow rate was 1.0 ml/min; detection was at 249 nm; with a 35  $\mu$ l injection volume.

The results (shown in Figure 12) are presented graphically, with the average percent of lobeline released from the six pouches plotted as a function of treatment duration. The time points set forth in the figure represent the average of six replicates. At the end of one week, the percent lobeline released from the pouch in the test samples was approximately 95%. The results indicate that substantially all of the lobeline contained in the microparticles is released by day seven.

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Example 8 - Materials and Methods - Efficacy Study  
of Lobeline Sulfate in Humans

Test Subjects

The test subjects consisted of long-term or chronic smokers who were smoking regularly for more than five years. They were smoking habitually 20 or more cigarettes per day. All volunteers were healthy, non-obese, male adults without history of gastrointestinal, hepatic, neurological or hematological abnormalities. Prior to enrollment for the study, each volunteer was examined for normalcy.

Method

On days 1, 2, 3, and 4 of the drug administration test, a quantity of 0.4, 0.6, 0.8 or 1 ml of 20 mg/ml lobeline sulfate solution was injected subcutaneously on the upper 1/3 of ventral aspect of the forearm. The volunteers were then free to smoke as per their desire and report on the number of cigarettes smoked and puffs taken for 2 hours after the injection.

Results

Both the number of cigarettes smoked and the number of puffs taken in the period of 2 hours after lobeline injection decreased as the dose given increased. The results are illustrated in Figures 10 and 11. As shown in figure 10, the average number of cigarettes smoked in a two hour period immediately following treatment with lobeline sulfate decreased

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substantially linearly as a function of the lobeline dose. Similarly, the average number of puffs taken in a two hour period immediately after treatment with lobeline sulfate decreased markedly as lobeline increased, although the initial effects were not observed until a dose of at least 12 milligrams was administered.

Example 9 - Materials and Methods - Efficacy Study of Lobeline-Containing Microparticles in Humans

Test Subjects

A total of twelve volunteers (9 test subjects and 3 placebo subjects) were selected according to the criteria described above in Example 8. With the exception of two volunteers who smoked 7 and 10 cigarettes per day, the remaining volunteers smoked, on average, approximately 20 cigarettes per day.

Formulation

A formulation comprising PLGA microparticles containing lobeline was prepared according to the method described in Example 1. However, the concentration of lobeline was adjusted to provide microparticles containing 35% lobeline by weight. Prior to injection, the formulation was resuspended in a diluent (D-mannitol (50 mg), carboxymethyl cellulose sodium (5 mg), polysorbate-80 (1 mg) and water for injection Q.S. to 1 ml) to form a homogeneous suspension.

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### Method

On days 1 and/or 2 of the drug administration test, a quantity of between approximately 0.6 ml to 0.8 ml of the above-described lobeline suspension was injected subcutaneously as described in Example 8. The volunteers were then free to smoke as per their desire and report on the number of cigarettes smoked for eight days. These results are shown in Figure 13, where day 1 represents the first full day following initial injection.

### Results

The number of cigarettes smoked in the period following the injections decreased in comparison to the number of cigarettes consumed prior to injection. The results are illustrated in Figure 13. As shown in figure 13, the number of cigarettes smoked in a 24 hour period compared to the number of cigarettes smoked prior to treatment is reported as the % cigarettes smoked. This percentage decreased substantially following injection of the lobeline suspension.

### EQUIVALENTS

Those skilled in the art will be able to ascertain, using no more than routine experimentation, many equivalents of the specific embodiments of the invention described herein.

These and all other equivalents are intended to be encompassed by the following claims.

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CLAIMS

1. A method of treating an individual for a drug dependence comprising, administering at least one physical constraint modulation system to said individual, said physical constraint modulation system releasing an amount of a drug substitute effective to diminish the individual's desire for a drug of abuse for a period of time having a duration of at least one day.

2. The method of claim 1 further comprising administering behavior modification counseling to said individual as part of a drug cessation program.

3. The method of claim 1 wherein said physical constraint modulation system is a transdermal patch.

4. The method of claim 1 wherein said physical constraint modulation delivery system is administered subcutaneously, intramuscularly or by implantation.

5. The method of claim 4 wherein said physical constraint modulation system is a biodegradable polymer, said polymer releasing said drug substitute as said polymer is biodegraded.

6. The method of claim 5 wherein said biodegradable polymer is selected from the group consisting of poly(lactic/glycolic)acid copolymers,

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polylactic acid, polyglycolic acid, polyesters, polyorthoesters, polylactones, polyanhydrides, and polyaminoacids.

7. The method of claim 6 wherein said biodegradable polymer is poly(lactic/glycolic) acid polymer.

8. The method of claim 7 wherein said poly(lactic/glycolic) acid polymer is about 50:50 to about 85:15 lactide glycolide.

9. The method of claim 7 wherein said biodegradable polymer is in the form of microparticles.

10. The method of claim 9 wherein said microparticles are of a size of about 38 to about 250  $\mu\text{m}$ .

11. The method of claim 7 wherein said biodegradable polymer is carried in a pharmaceutically acceptable injection vehicle.

12. The method of claim 11 wherein said pharmaceutically acceptable injection vehicle comprises a solution of carboxymethylcellulose.

13. A drug delivery system for treating a drug comprising,  
a physical constraint modulation system



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constructed and arranged to release a therapeutic level of a drug substitute to an individual in a controlled, sustained release manner for a period of time having a duration of at least one day.

14. A drug delivery system as claimed in claim 13 wherein the physical constraint modulation system is a transdermal patch.

15. A drug delivery system as claimed in claim 13 wherein said physical constraint modulation system is a biodegradable polymer capable of subcutaneous or intramuscular injection or implantation.

16. A drug delivery system as claimed in claim 15 wherein the physical constraint modulation system delivers the drug substitute into the circulatory system.

17. A drug delivery system as claimed in claim 15 wherein the biodegradable polymer is selected from the group consisting of poly(lactic/glycolic)acid copolymers, polylactic acid, polyglycolic acid, polyesters, polyorthoesters, polylactones, polyanhydrides, and polyaminoacids.

18. The drug delivery system as claimed in claim 17 wherein said biodegradable polymer is poly(lactic/glycolic) acid polymer.

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19. The drug delivery system as claimed in claim 18 wherein said poly(lactic/glycolic) acid polymer is about 50:50 to about 85:15 lactide/glycolide.

20. A drug delivery system as claimed in claim 18 wherein the microparticles are of a size of about 38 to about 250  $\mu\text{m}$ .

21. A drug delivery system as claimed in claim 18 wherein the biodegradable polymer is in the form of microparticles suspended in a pharmaceutically acceptable injection vehicle.

22. A drug delivery system as claimed in claim 21 wherein the pharmaceutically acceptable injection vehicle comprises a solution of carboxymethylcellulose.

23. A drug delivery system as claimed in claim 13 wherein the said period of time has a duration of at least seven days.

24. A drug delivery system as claimed in claim 23 wherein said period of time has a duration of at least thirty days.

25. A drug delivery system as claimed in claim 14 wherein the transdermal patch contains the drug substitute in a diffusion matrix layer.

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26. A drug delivery system as claimed in claim 25 wherein the diffusion matrix layer further contains a non-solvent absorption enhancer.

27. A drug delivery system as claimed in claim 25 wherein the diffusion matrix layers further contains an anti-pruritic agent.

28. A drug delivery system as claimed in claim 14, said transdermal patch having a first compartment and a second compartment, said first compartment holding the drug substitute and said second compartment holding a delivery substance, said patch constructed and arranged such that the drug substitute is not released from the patch in therapeutically significant amounts until contacted with the delivery substance.

29. A drug delivery system as claimed in claim 28 wherein the delivery substance is an alcohol or an aqueous alcohol solution.

30. A drug delivery system as claimed in claim 28 wherein the second compartment further contains an absorption enhancer.

31. The drug delivery system as claimed in claim 28, wherein said drug substitute is selected from a group of drug substitutes consisting of drugs for treating heroin dependence, non-opiate sedative

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dependence, benzodiazepine dependence, cocaine dependence and alcohol dependence.

32. The drug delivery system of claim 13, wherein said drug substitute is a drug for treating heroin dependence and is selected from the group of drugs consisting of dl-methadone, l-methadone, naltrexone, buprenorphine, and levo-alpha acetylmethadol.

33. The drug delivery system of claim 13, wherein said drug substitute is a drug for treating non-opiate sedative dependence and is selected from the group of drugs consisting of phenobarbitol, chlordiazepoxide, and diazepam.

34. The drug delivery system of claim 13, wherein said drug substitute is a drug for treating benzodiazepine dependence and is selected from the group of drugs consisting of long-acting benzodiazepines comprising chlorzepate, diazepam, and flurazepam.

35. The drug delivery system of claim 13, wherein said drug substitute is a drug for treating cocaine dependence and is selected from the group of drugs consisting of bromocriptine, desipramine, buprenorphine, amfebutamone, carbamazepine, fluoxetine, flupenthixol, maprotilene, gepirone, and mazindol.

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36. The drug delivery system of claim 13, wherein said drug substitute is a drug for treating alcohol dependence and is selected from the group of drugs consisting of naltrexone, buspirone, fluoxetine, ondansetron, disulfiram, nadide, nitretazole, and calcium cyanamide citrated.

37. A kit useful in treating a drug dependence comprising,

at least one physical constraint modulation system constructed and arranged to release a therapeutic level of a drug substitute to an individual in a controlled, sustained release manner for a period of time having a duration of at least one day; and

instructions providing information to the user regarding the use of the delivery system for treating the drug dependence.

38. A kit as claimed in claim 37 wherein said drug dependence is selected from the group consisting of heroin dependence, non-opiate sedative dependence, benzodiazepine dependence, cocaine dependence and alcohol dependence.

39. A kit as claimed in claim 37 wherein said drug dependence is heroin dependence and said drug substitute is selected from the group consisting of dl-methadone, l-methadone, naltrexone, buprenorphine, and levo-alpha acetylmethadol.

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40. A kit as claimed in claim 37 wherein said drug dependence is non-opiate sedative dependence and said drug substitute is selected from the group consisting of phenobarbitol, chlordiazepoxide, and diazepam.

41. A kit as claimed in claim 37 wherein said drug dependence is benzodiazepine dependence and said drug substitute is selected from the group consisting of long-acting benzodiazepines comprising chlorzepate, diazepam, and flurazepam.

42. A kit as claimed in claim 37 wherein said drug dependence is cocaine dependence and said drug substitute is selected from the group consisting of bromocriptine, desipramine, buprenorphine, amfebutamone, carbamazepine, fluoxetine, flupenthixol, maprotilene, gepirone, and mazindol.

43. A kit as claimed in claim 37 wherein said drug dependence is alcohol dependence and said drug substitute is selected from the group consisting of naltrexone, buspirone, fluoxetine, ondansetron, disulfiram, nadide, nitretazole, and calcium cyanamide citrated.

44. A kit as claimed in claim 37 wherein said physical constraint modulation system is a transdermal patch.

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45. A kit as claimed in claim 37 wherein said period of time has a duration of at least seven days.

46. A kit as claimed in claim 37 wherein said period of time has a duration of at least thirty days.

47. A kit as claimed in claim 44 wherein the patches are one-day patches.

48. A kit as claimed in claim 44 wherein the patches are seven-day patches.

49. A kit as claimed in claim 44 wherein said transdermal patch has a first compartment and a second compartment, said first compartment holding a drug substitute and said second compartment holding a delivery substance, said transdermal patch constructed and arranged such that the drug substitute is not delivered from the transdermal patch in therapeutically significant amounts until contacted with the delivery substance.

50. A kit as claimed in claim 49 wherein the kit contains sufficient numbers of transdermal patches to permit long-term therapeutic levels of the drug substitute to be delivered to an individual.

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51. A kit as claimed in claim 50 wherein the first compartment contains an amount of the drug substitute sufficient to deliver a therapeutic amount of the drug substitute over a period of time having a duration of about seven days.

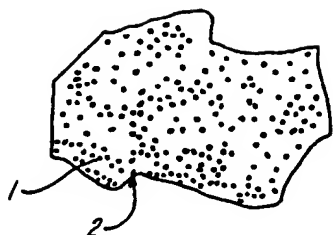
52. A kit as claimed in claim 51 wherein the first compartment contains an amount of the drug substitute sufficient to deliver a therapeutic amount of the drug substitute over a period of time having a duration of about thirty days.

53. A kit as claimed in claim 37 wherein the physical constraint modulation system is a subcutaneous delivery system.

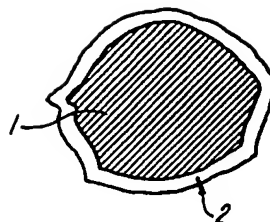
54. A kit as claimed in claim 53 wherein the physical constraint modulation system is a biodegradable polymer in the form of microparticles containing the drug substitute.

55. A kit as claimed in claim 54, further comprising a diluent for resuspending the physical constraint modulation system containing the drug substitute.

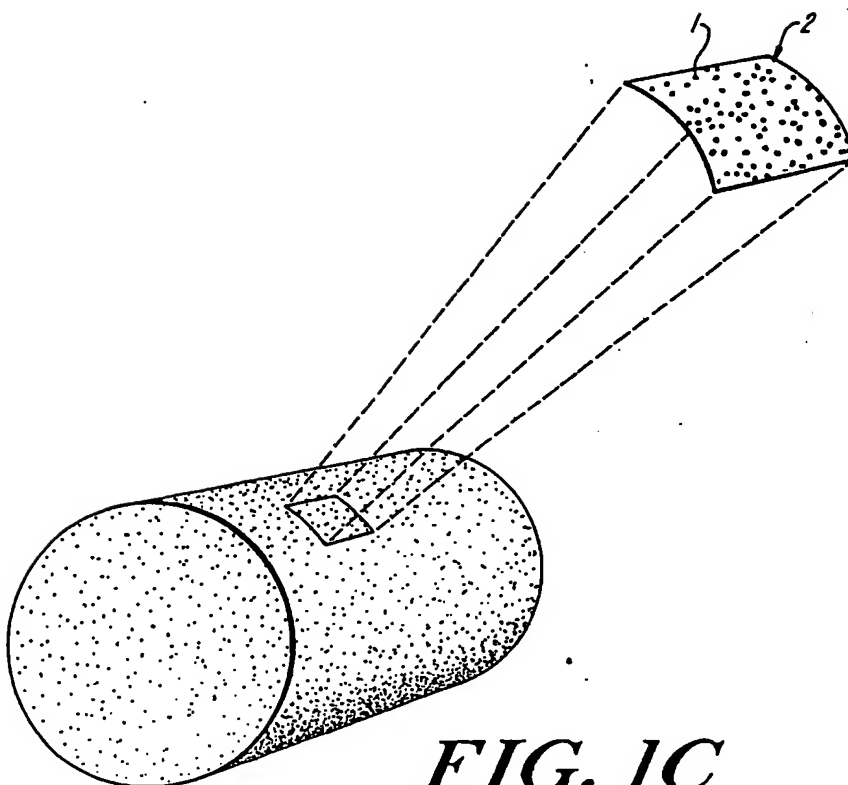




**FIG. 1A**

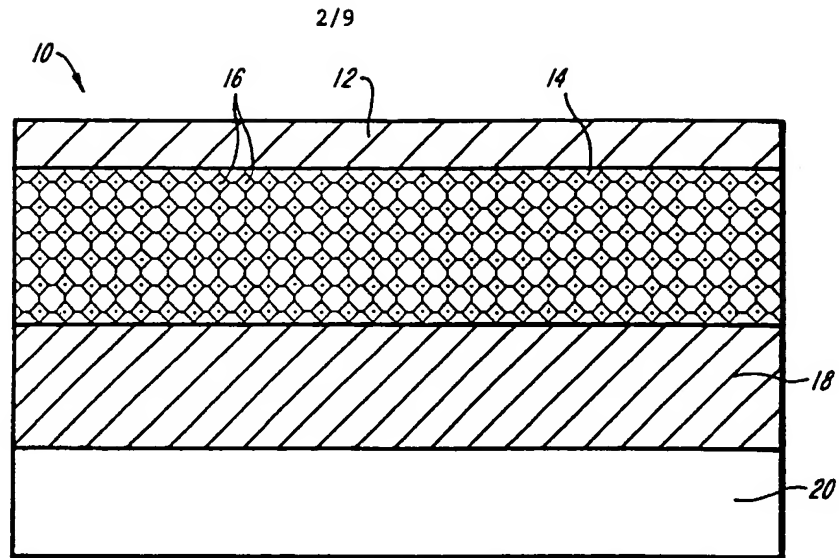


**FIG. 1B**

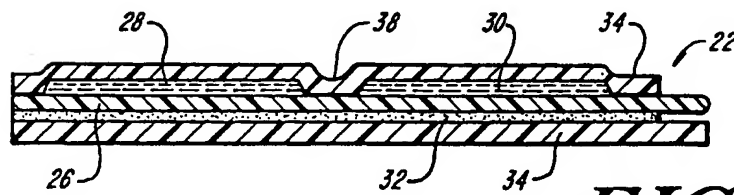


**FIG. 1C**

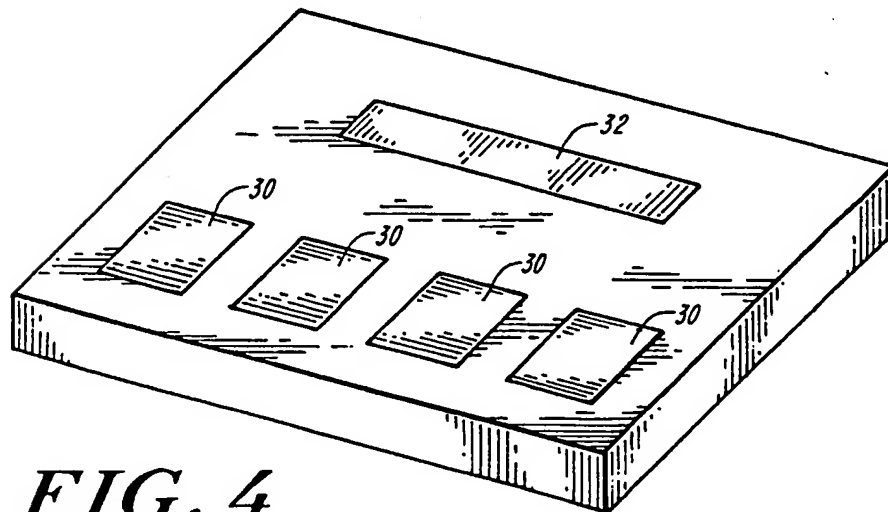
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**FIG. 2**



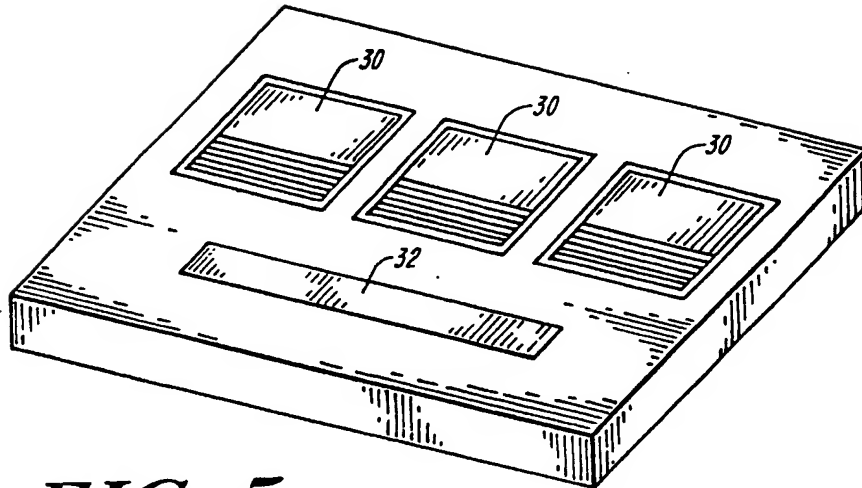
**FIG. 3**



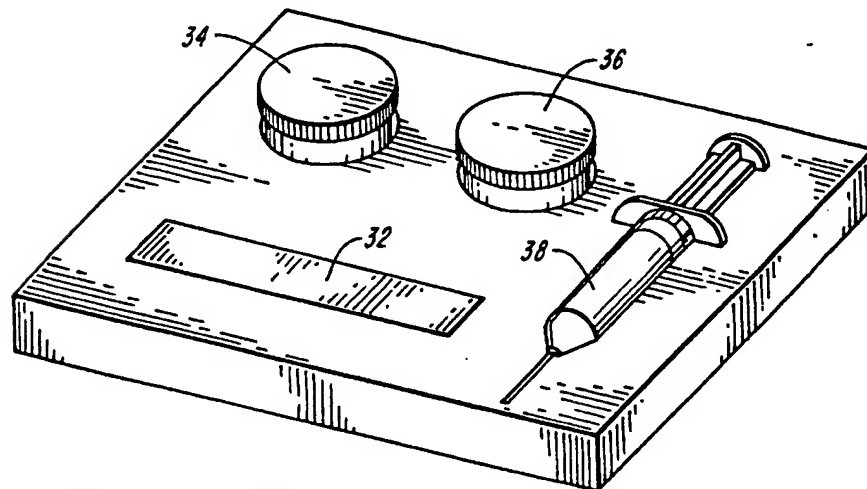
**FIG. 4**

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**FIG. 5**



**FIG. 6**

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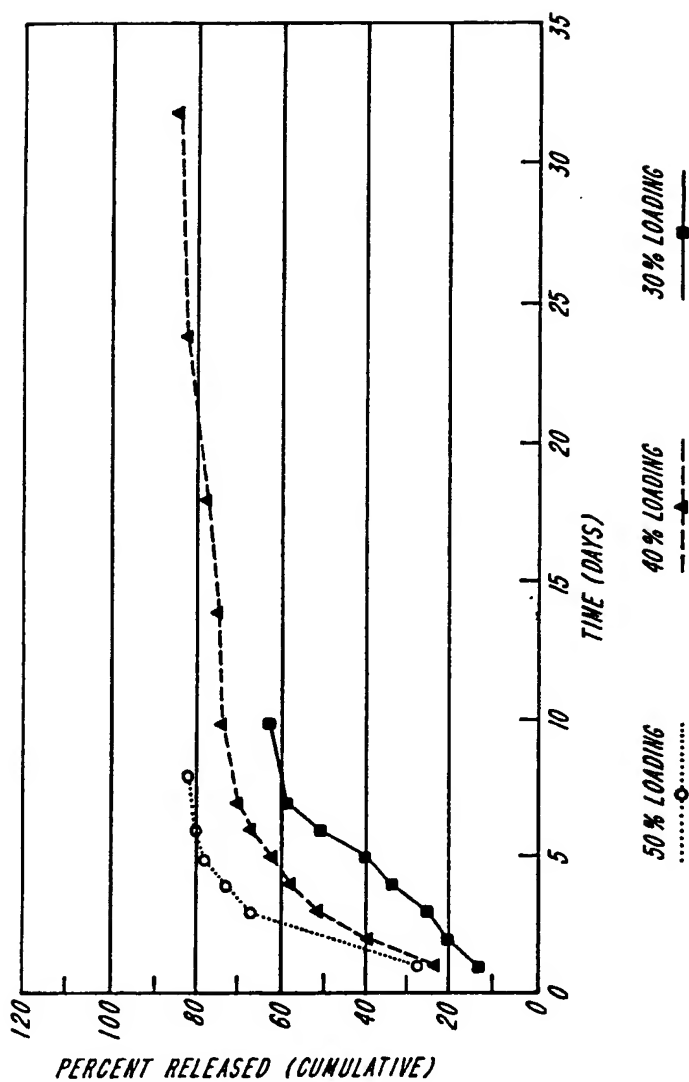
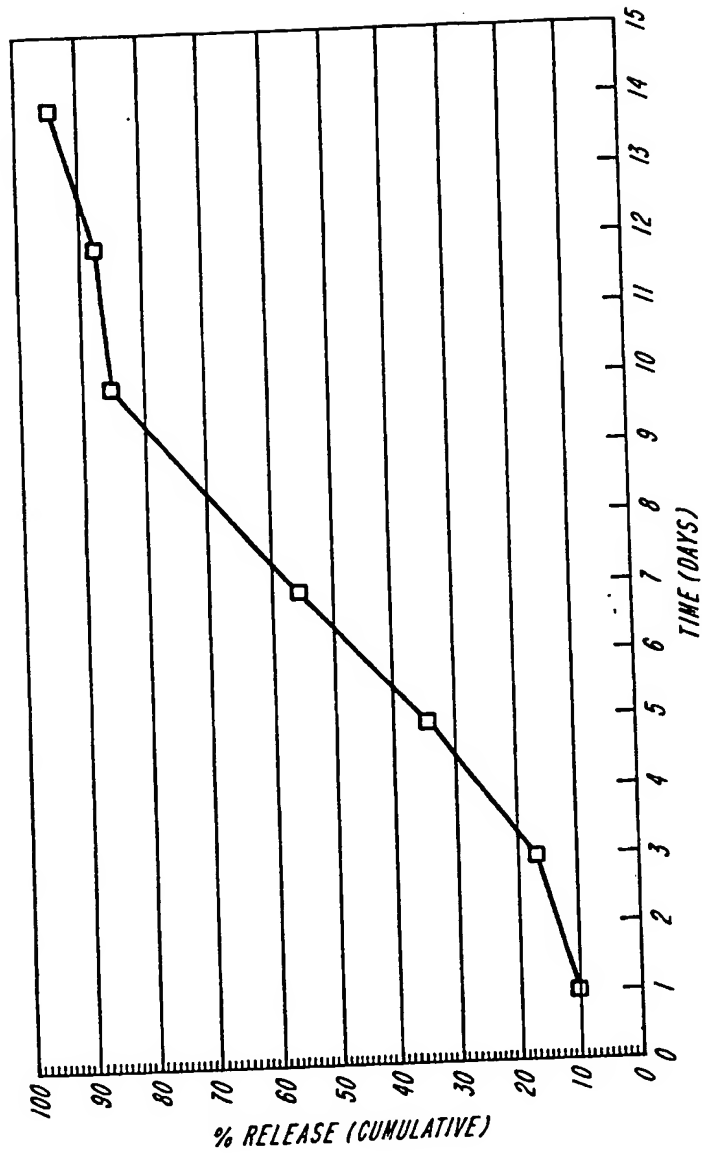


FIG. 7

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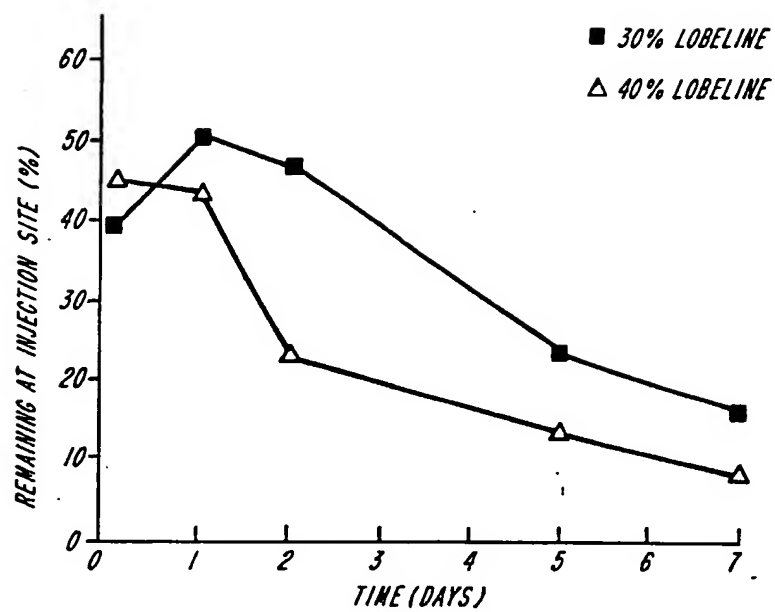


30% — □ —

**FIG. 8**

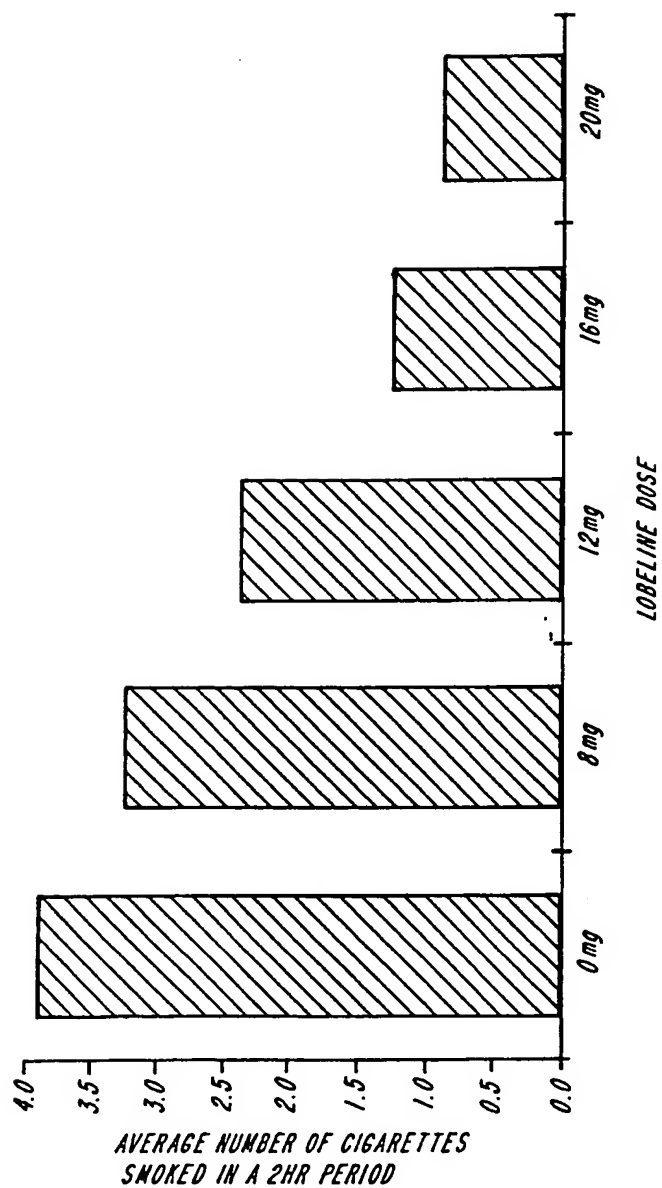
SUBSTITUTE SHEET

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**FIG. 9**

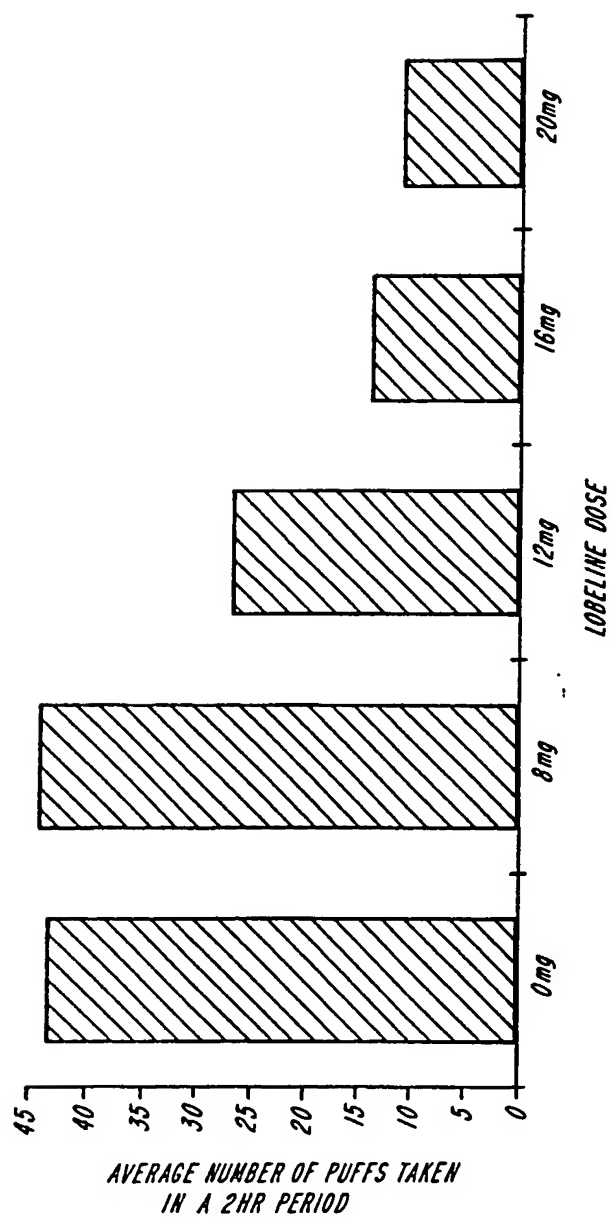
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**FIG. 10**

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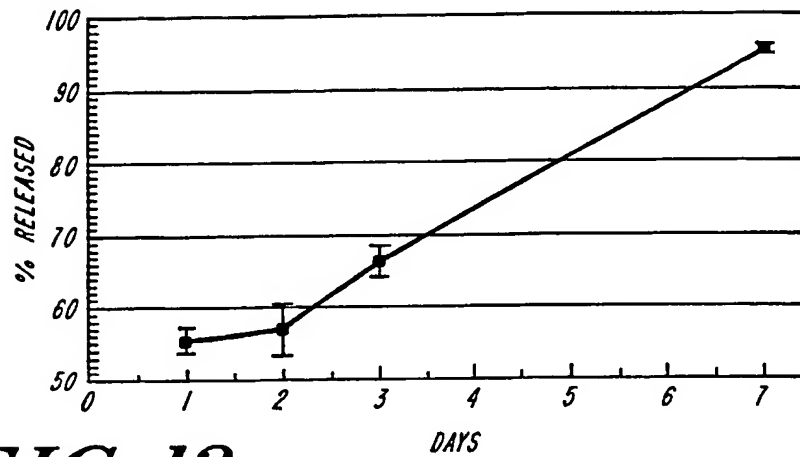
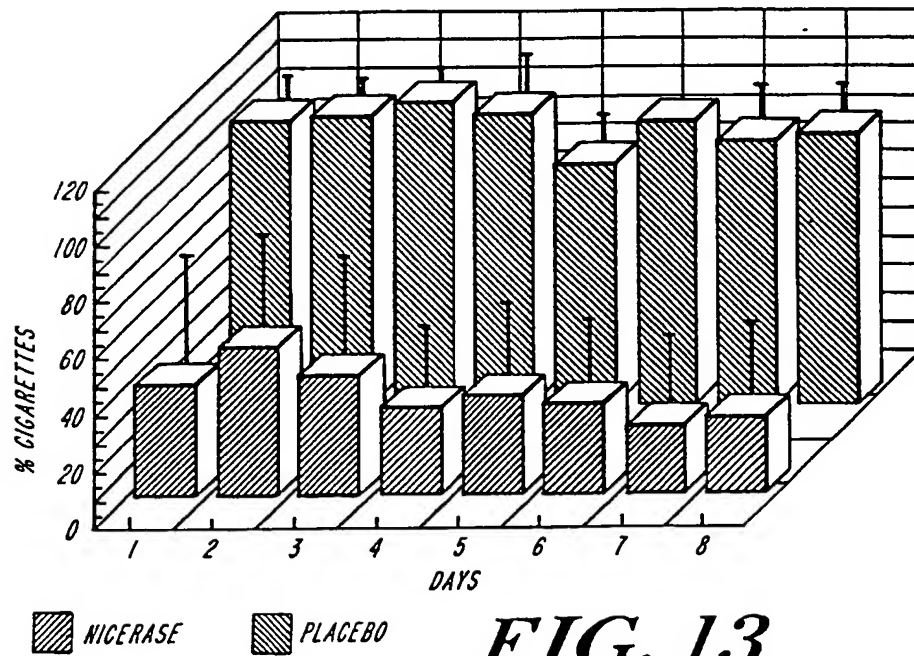
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**FIG. 11**

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*IN VIVO RELEASE OF LOBELINE FROM NICERASE***FIG. 12***TESTING OF NICERASE IN HUMANS***FIG. 13**

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/03859

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl.5                      A 61 K    9/16                      A 61 K    9/70		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl.5	A 61 K	
Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	P.B. DEASY: "Microencapsulation and related drug processes", 1984, Marcel Dekker, Inc., New York, US, see pages 223-224, chapter 10.1.2: "Narcotic antagonists"  <div style="text-align: center;">---</div>	1,2,4- 10,13, 15-20, 32-43, 45-46, 53-54
X	<div style="text-align: center;">---</div> Chemical Abstracts, vol. 96, no. 22, November 1981, (Columbus, Ohio, US), A.C. SHARON et al.: "Development of drug delivery systems for use in treatment of narcotic addiction", see pages 339-340, abstract no. 192313k, & NIDA RES. MONOGR. 1981, 28, 194-213, see the abstract <div style="text-align: center;">---                      -/-</div>	1,2,4- 10,13, 15-20, 32-43, 45-46, 53-54
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><sup>10</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
11-09-1992		30. 09. 92
International Searching Authority EUROPEAN PATENT OFFICE		Signature of Authorized Officer <i>Dagmar Föar</i>

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		Relevant to Claim No.
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	
X	Journal of Medicinal Chemistry, vol. 16, no. 8, August 1973, J.H.R. WOODLAND et al.: "Long-acting delivery systems for narcotic antagonists. I", pages 897-901, see the whole article	1,2,4- 13,15- 22,32- 43,45- 46,53- 55
X	Journal of Pharmaceutical Sciences, vol. 64, no. 2, February 1975, S. YOLLES et al.: "Long acting delivery systems for narcotic antagonists II: release rates of naltrexone from poly(lactic acid) composites", pages 348-349, see the whole article	1,2,4- 13,15- 22,32- 43,45- 46,53- 55
X	US,A,4678809 (PHILLIPS) 7 July 1987, see the whole document	36
X	EP,A,0178140 (ALZA CORP.) 16 April 1986, see the whole document, in particular page 8, line 9	3,13,14 ,37,44, 47
Y		25-31, 45,48- 52
Y	US,A,4917676 (HEIBER et al.) 17 April 1990, see the whole document (cited in the application)	25-31, 45,48- 52
Y	EP,A,0272918 (CYGNUS RESEARCH CORP.) 29 June 1988, see the whole document & US,A,4911916 (cited in the application)	25-31, 45,48- 52
P,A	EP,A,0432945 (WARNER-LAMBERT CO.) 19 June 1991, see the whole document	3

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9203859  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 24/09/92. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU-B- 575760	04-08-88
		AU-A- 4842785	12-06-86
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		ZA-A- 8708657	20-05-88
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		AU-A- 8249987	23-06-88
		JP-A- 63190823	08-08-88
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